Title:
Wheelchair Controlled by Head Motion Interaction

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Abstract:
Electric wheelchairs are designed to aid paraplegics. Unfortunately, these cannot be used by persons with higher degree of impairment, such as quadriplegics, i.e. persons that, due to age or illness, cannot move any of the body parts, except of the head. Target of this project is to develop a solution able to move the wheelchair by the movement of the head. With an accelerometer which is placed on a cap, which is worn by the patient, it's possible to obtain the head motion recognition. By means of the accelerometer data processing, stepper motors are controlled in order to move the joystick of an electric wheelchairs.

Introduction:
Quadriplegics are persons who are not able to use any of the extremities [1, 2]. The reasons for such decreased motion possibilities can be different: stroke, arthritis, high blood pressure, degenerative diseases of bones and joints and cases of paralysis and birth defects. Also, quadriplegia appears as a consequence of accidents or age. The patients with such severe disabilities are not able to perform their everyday actions, such as: feeding, toilette usage and movement through space [3, 4]. Depending on the severity of the disability, a patient can retain freedom of movement to a certain level by using different medical devices. Mobility has become very important for a good quality of life. Designing a system with independent mobility for such disabled people is our aim in this project. A prototype of the system is implemented and experimentally tested. The prototype consists of the digital system (an accelerometer and a micro-controller) and a mechanical actuator. The accelerometer is used to gather head motion data. To process the sensors data, an algorithm is implemented using a micro-controller. The output of the digital system is connected with the mechanical actuator, which is used to position the wheelchair joystick in accordance with the user's command. Sensor data is processed by an algorithm, implemented within the micro-controller. Thus, user head motion is translated into electric wheelchair joystick position.
Moreover an Unity application is realized in order to help the patient become confident with the different commands. It's divided in two different parts: tutorial and free-mode. During the tutorial the patient understands which are the principal movements of the head while during the free-mode it's possible to move freely in a virtual space without any limitations.

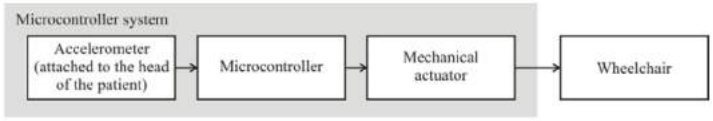

Fig. 1: Project block diagram.

Fig. 2: Joystick motion system.

Recognition of the movement:

Motion recognition is a process in which a receiver recognizes user's motion. In our case in order to measure the head position an accelerometer is mounted on the cap which is worn by the patient. When the head is moved over a certain threshold angle accelerometer ADXL335 elaborates this information. The ADXL335 sensor is a capacitive accelerometer. It works on the principle that when an acceleration is applied to the sensor, the capacitance inside the sensor changes. This change in capacitance is then measured as an electric signal and used to measure the acceleration of the object. It is a 3-axis accelerometer, so it can be used to calculate accelerations in all directions. The ADXL335 sensor has 6 pins and an integrated chip on the front of the board. The pins are soldered at the back of the board. VCC pin is used for the power supply, X-out is the output to measure the acceleration along the x-axis, Y-out is the output to measure the acceleration along the y-axis, Z-out is the output to measure the acceleration along the z-axis and GND is the ground pin.

All the possible angular positions of the head the patient might assume are divided into a certain number of sectors: once the person enter in a defined section a corresponding zone-number is obtained as an output.

A part of the code of Arduino is considered in order to better understand the procedure. Every time that the patient goes over a certain threshold angle the variable "a" or "b" assume a defined value. Integer values where used since the maximum value that can be sent to Unity from Arduino is limited to 128.

Fig. 3: Accelerometer ADXL335.

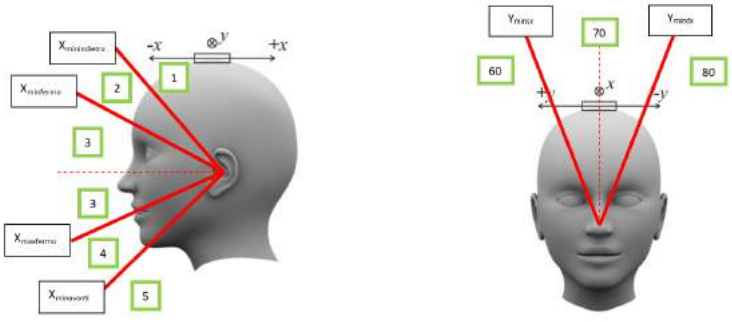

Fig. 4: Threshold angles.

Physical prototype:

In order to permit the movement a mechanical system with two stepper motors has been developed. It permits to control the displacement of the joystick.

With this mechanism it's possible to move the joystick in four main different position: forward-backward and left/right. Movement is realized by a series of gears as shown in the following image.

Conclusion:

This paper shows the design and manufacturing of a system which controls a wheelchair using head movements. Threshold setup of the head angle position is a critical procedure. This is due to the fact that different people behave in different ways and an absolute global value cannot be defined. Another reason is that the best thing for the user is to move as little as possible the head to avoid taking his eyes off the road and to minimize movements of the head. This means minor threshold but this would lead to greater sensor sensitivity. During the test an electrical wheelchair with rear traction is used. This type of wheelchairs present some problem during rotations due to the couple of little wheels on the front that are an obstacle sometimes.

References:

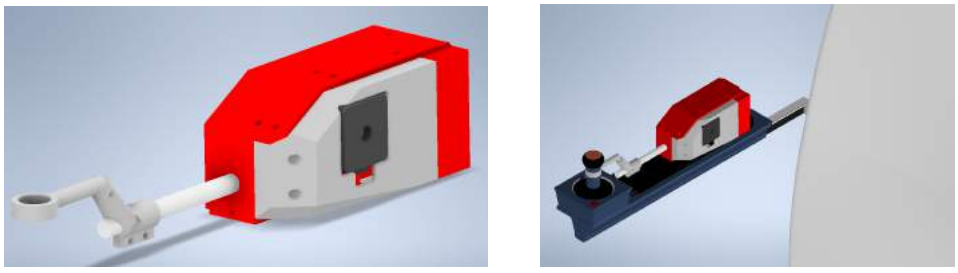

Fig. 5: Assembly 3D model.

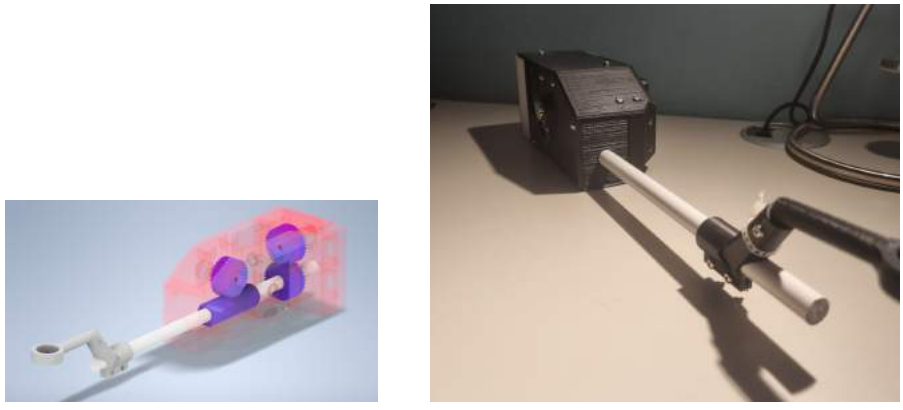

Fig. 6: Physical prototype.

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